NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3710

PRELIMINARY INVESTIGATION OF THE EFFECTS OF EXTERNAL WING FUEL TANKS ON DITCHING BEHAVIOR OF A SWEPTBACK-WING AIRPLANE

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SUMMARY

An experimental investigation was made by use of a 1/10-scale dynamically similar model of a typical sweptback-wing airplane equipped with external wing fuel tanks to determine the effects of the tanks on the ditching behavior. Tanks of various fuel capacity (206, 260, and 450 gallons full-scale) and with several shape modifications were used. The model was landed in calm water at the Langley tank no. 2 monorail.

The ditching behavior of the model, both with and without tanks, was determined from visual observations, acceleration records, and motion pictures of the ditchings. Data are presented in tabular form, time-history curves of acceleration and attitude, and sequence photographs.

From the results of the investigation, it is concluded that streamline tanks with circular cross section have a detrimental effect on the ditching behavior because of the suction forces generated on such shapes when planing on the water. Such tanks should, therefore, be jettisoned before a ditching is attempted. Tanks having their cross section modified by the addition of either chine strips or dead rise with chines improved the ditching behavior of the airplane model. Before an attempt is made to incorporate such modifications in a full-scale airplane, however, consideration must also be given to providing a structural design that would withstand the water loads.

INTRODUCTION

Model-ditching experience of airplanes equipped with auxiliary wing tanks has shown that the design and location of these tanks can have considerable influence on the success of a ditching. On unswept-

[1]The information presented in the present paper on the basic model and the model with 206-gallon tanks was previously made available to the U. S. military air services in 1949.

wing airplanes, the fuel tanks are normally located at the wing tips and seldom enter the water until the airplane comes to rest; consequently, the ditching behavior is little affected. On swept-wing airplanes, the tanks are usually mounted beneath the wing and enter the water very soon after contact. If the shape of underslung tanks is such that a suction force is produced, a detrimental effect on the ditching behavior may result. Reference 1 has shown that an increase in fineness ratio decreases the suction forces on a streamline body. Also, the additional buoyancy provided by wing tanks from which the fuel had been expended would add to the flotation time of the airplane and facilitate the pilot's rescue. Thus, with the advent of larger-volume ferry-type tanks of higher fineness ratio, such as have been used on modern swept-wing airplanes, the possibility of using the external wing tanks as an aid to ditching is of interest.

The purpose of this investigation is to provide data from some preliminary research into the effects of external wing fuel tanks on the ditching behavior of an airplane with sweptback wings. Use was made of an available 1/10-scale model of a typical swept-wing airplane with underslung tanks. (For purposes of presentation, the model data are given in terms of full-scale values.) The basic configuration without tanks and with the 206-gallon (fineness ratio 4.76) tanks originally proposed for this airplane was first tested in 1949 at Langley tank no. 2. For the present investigation, two additional tanks (450-gallon and 260-gallon) of fineness ratio 8.54 were tested with various modifications to the cross section. Results for all configurations are compared to evaluate the effects of these tanks on the ditching behavior of the airplane.

APPARATUS AND PROCEDURE

Description of Model

Figure 1 is a three-view drawing of the basic sweptback-wing airplane used in the investigation. The 1/10-scale model of this airplane was constructed principally of fiber glass impregnated with plastic. The model was ballasted internally to a weight (full-scale) of about 17,000 pounds. The full-scale moments of inertia were as follows:

Moment of inertia about X-axis, I_X (roll), slug-ft^2 10,700
Moment of inertia about Y-axis, I_Y (pitch), slug-ft^2 20,400
Moment of inertia about Z-axis, I_Z (yaw), slug-ft^2 28,300

All tests were made with no bottom damage simulated.

Figure 2 is a photograph of the model with the 450-gallon tanks of circular cross section installed. All tanks were molded of fiber glass and plastic and attached directly to the lower surface of the wing at an angle of -4.25° to the fuselage reference line for a minimum aerodynamic drag. The tanks were located 8 feet outboard of the fuselage center line with the centroid of the tank directly below the airplane center of gravity.

The tank configurations tested are shown in figure 3. The 206-gallon tanks had a fineness ratio of 4.76 while both the 450- and the 260-gallon tanks had a fineness ratio of 8.54. Only the circular-cross-section shape was used on the 206-gallon tanks. The three cross-section shapes shown in figure 3 were tested on both the 450- and 260-gallon tanks. Chine strips protruding 1.25 inches full-size were added to the tanks along the 45° streamlines. These strips continued along the full length of each of the tanks except where they were faired down at the nose and tail ends of the tank. The tanks were also modified by the addition of a 20° dead-rise bottom and vertical sides which also produced a chine. The volume of each of the tanks was kept the same in this modification.

Test Methods and Equipment

The model was tested by catapulting it from the Langley tank no. 2 monorail so that it was free to glide onto the water at the desired contact angle and landing speed. The control surfaces were set so that the model did not yaw or change attitude appreciably in flight.

All tests were made at the normal landing attitude for this airplane (about 14°) and a landing speed corresponding to about 109 knots full-scale. The behavior of the model was recorded from visual observations and by a high-speed motion-picture camera. The attitude time histories were read from the motion-picture film. Accelerations were recorded by a two-component time-history accelerometer installed in the cockpit. The accelerometer components had natural frequencies of 73 cycles per second and were damped to about 65 percent of the critical damping value. The reading accuracy of the instrument was about $\pm 0.25g$, and the normal accelerations included the 1g effect of gravity.

RESULTS AND DISCUSSION

A summary of the test results obtained with the various tank configurations and those of the basic model without tanks is given as full-scale values in table I. Typical time histories of the attitude, the longitudinal deceleration, and the normal acceleration are given in figure 4. Figure 5 shows sequence photographs of ditching runs of the basic model without tanks, with the 450-gallon tanks of circular cross section, and with the 450-gallon dead-rise tanks installed.

Basic Model and Original 206-gallon Tanks

First, it should be pointed out that the ditching behavior of the basic undamaged model without tanks was good. (See figs. 4(a) and 5(a).) The motions of the model were smooth, the length of run was reasonably long (and indicated low average deceleration), and the maximum longitudinal deceleration and normal acceleration were low. The addition of the original 206-gallon tanks had a detrimental effect on the ditching behavior. (See fig. 4(b).) The length of the run was much shorter, the longitudinal deceleration was much higher, and the motions and attitude changes were quite severe. This behavior was caused by the suction forces generated by the circular streamline shape of the tanks which effectively dragged the model deeper in the water and caused higher water resistance. Such behavior was also encountered in an investigation of the effect of fuselage shape on ditching behavior (ref. 1), where suction forces on the streamline fuselage caused the model to run deep in the water.

Model With 450-Gallon Tanks

When the model was tested with the 450-gallon tanks installed (figs. 4(c) and 5(b)), the ditching characteristics were better than those obtained with the original 206-gallon tanks installed. The length of the run was longer and the longitudinal deceleration was lower. This improvement in behavior is attributed to a reduction in the suction forces on the tanks which results from the decrease in curvature associated with the increase in fineness ratio. It was also determined in reference 1 that an increase in fineness ratio reduced the suction effect of a streamline body. The behavior of this configuration, however, was not so good as that of the basic model without tanks.

Installation of chine strips (fig. 4(d)) improved considerably the ditching behavior of the model with the 450-gallon tanks. The strips broke the lateral flow of water up the sides of the tanks and thereby reduced the suction forces. The addition of the strips increased the length of the run by more than 300 percent, reduced the maximum longitudinal deceleration by about 60 percent, and reduced the normal acceleration by about 33 percent. Also, the longitudinal deceleration was lower and the length of run was longer than that obtained from the basic model without tanks. Some slight skipping and porpoising were observed, but the overall behavior of the basic model was considered to have been improved by the addition of the 450-gallon tanks with the chine strips. Skipping is defined as an undulating motion about the transverse axis in which the model clears the water completely. Porpoising is defined as an undulating motion about the transverse axis in which some part of the model is always in contact with the water.

When the model was tested with the tanks having a 20° dead-rise bottom (figs. 4(e) and 5(c)), the maximum longitudinal deceleration was further reduced and the length of run of the model increased slightly. The main improvement was the elimination of the skipping and a reduction in amplitude of the porpoising cycle when compared with that of the tank configuration with chine strips.

Model With 260-Gallon Tanks

The 260-gallon tanks (figs. 4(f), 4(g), and 4(h)) had less effect on the behavior of the model than did the 450-gallon tanks. The behavior of the basic model without tanks was preferable to that of the model with tanks of circular cross section installed. An improvement in behavior was noticed when the 260-gallon tanks were modified by the addition of either chine strips or the 20° dead-rise bottom with chines, as was the case with the larger tanks.

General

All tanks having a circular-cross-section shape produced adverse effects, and better ditchings were made with the basic model than with any of these tanks regardless of size or fineness ratio. It can be concluded, therefore, that these tanks should be jettisoned before a ditching is attempted. However, the tanks having their cross-sectional shape modified by either chine strips or dead rise with chines aided the ditching performance. It should be emphasized that the results of this investigation are essentially preliminary. If it should be desired to incorporate any of the modifications discussed in full-scale airplanes, certain structural problems should be considered and the tanks should be hydrodynamically satisfactory. Generally, tank fittings are designed to withstand a normal deceleration of at least 4g and a longitudinal deceleration of 2g. From the maximum values of normal acceleration listed in table I it can be seen that the tanks with circular cross sections might be torn away upon contact with the water. The attachments for the tanks modified by chine strips or dead rise could withstand the acceleration loads in a calm water landing but the tanks would have to be designed to withstand water loads. Deformation of the tank skin would change the hydrodynamic characteristics of the tanks, the resulting behavior depending on the amount of damage. Rupture of the tank skin would very probably produce adverse effects on ditching behavior such as loss of buoyancy, higher deceleration, and possibly a dangerous diving motion.

CONCLUDING REMARKS

From the results of a model investigation of the effects of external wing fuel tanks on the ditching behavior of a sweptback-wing airplane it was concluded that the streamline tanks with circular cross section have a detrimental effect on the ditching behavior with respect to the basic model because of the suction forces generated on such shapes when planing on the water. These tanks should, therefore, be jettisoned before a ditching is attempted. The tanks having their shape modified by the addition of either chine strips or dead rise with chines improved the ditching behavior. Before an attempt is made to incorporate such modifications in a full-scale airplane, however, consideration must also be given to providing a structural design that would withstand the water loads.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 2, 1956.

REFERENCE

1. McBride, Ellis E., and Fisher, Lloyd J.: Experimental Investigation of the Effect of Rear-Fuselage Shape on Ditching Behavior. NACA TN 2929, 1953.

TABLE I

SUMMARY OF TEST RESULTS OBTAINED WITH VARIOUS TANK CONFIGURATIONS

[All values are full-scale]

Tank configuration	Maximum longitudinal deceleration, g units	Maximum normal acceleration, g units	Length of run, ft	Remarks
Basic, without tanks	1.6	4.0	640	Smooth run
206-gal. circular	5.5	---	200	Deep run with violently changing attitude
450-gal. circular	3.3	4.8	350	Deep run at high attitude
450-gal. circular with chines	1.2	3.2	1,100	Slight skipping and porpoising
450-gal. 20° dead rise with chines	0.5	3.2	1,200	Gentle porpoising
260-gal. circular	2.4	5.3	400	Deep run at high attitude
260-gal. circular with chines	1.0	3.3	700	Smooth run
260-gal. 20° dead rise with chines	1.5	3.7	750	Smooth run

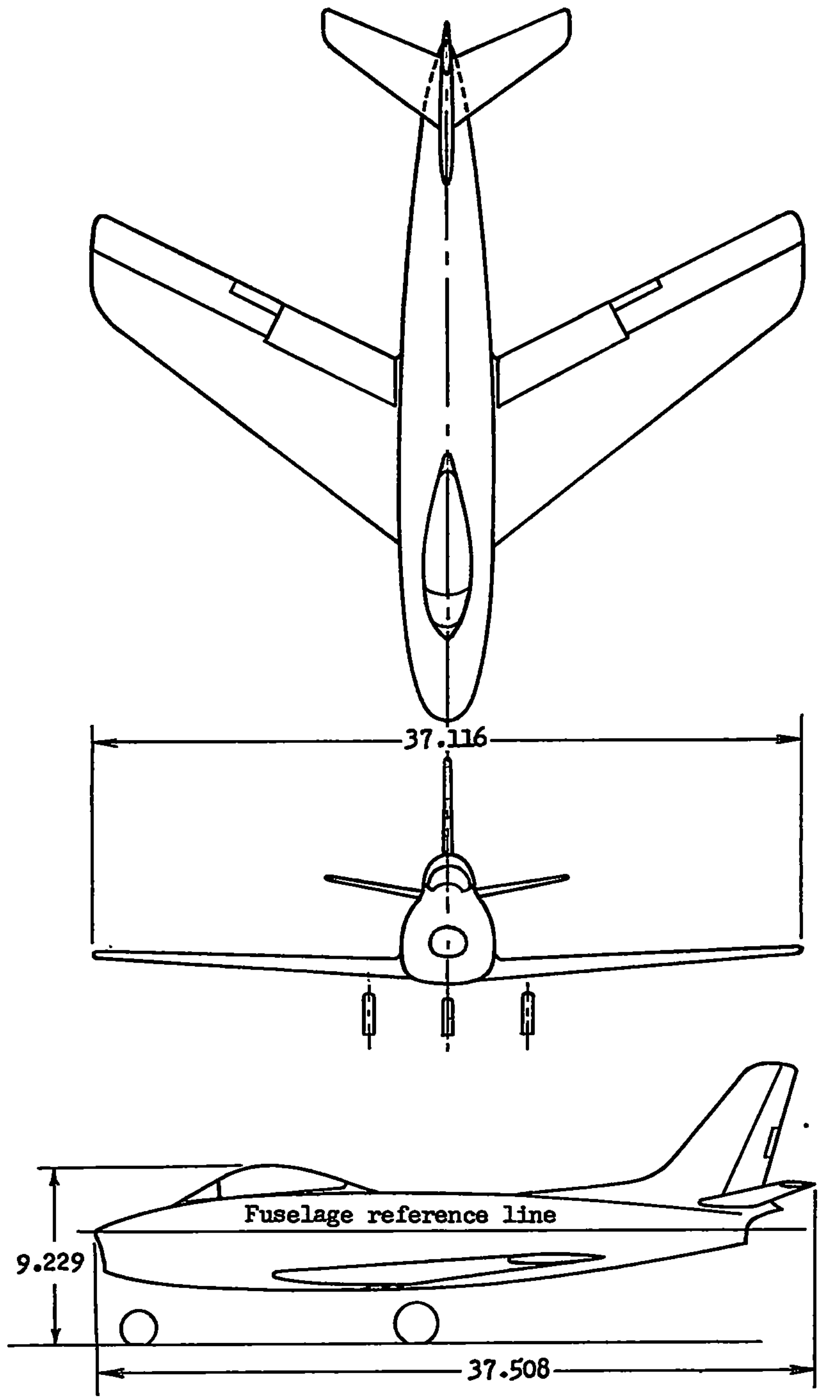
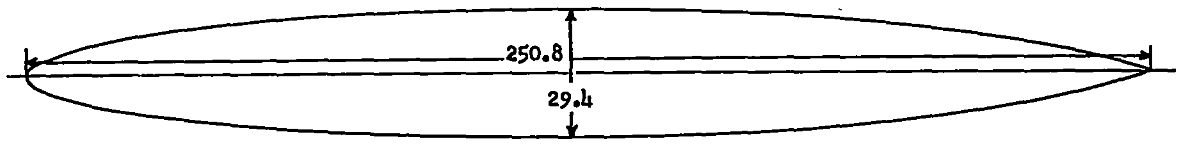


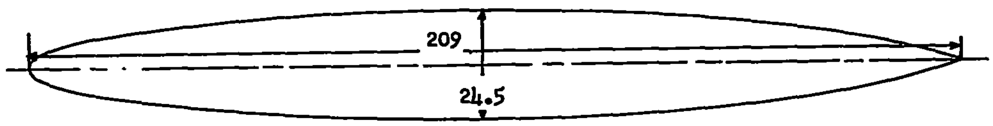
Figure 1.- Three-view drawing of the swept-wing airplane. All dimensions are in feet, full-scale.

L-90165

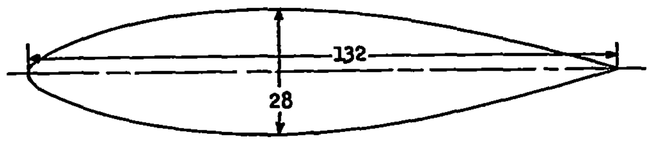
Figure 2.- Model with 450-gallon circular-cross-section tanks installed.



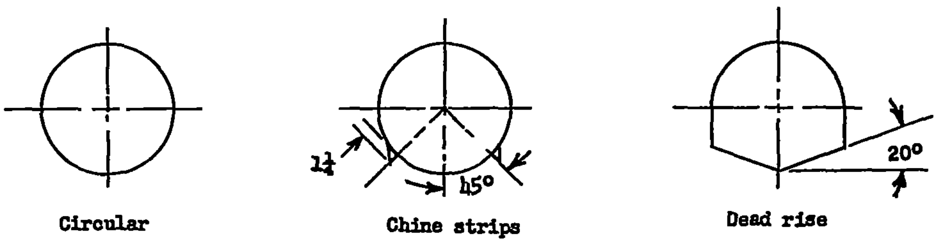
(a) 450-gallon tank. Fineness ratio, 8.54.



(b) 260-gallon tank. Fineness ratio, 8.54.

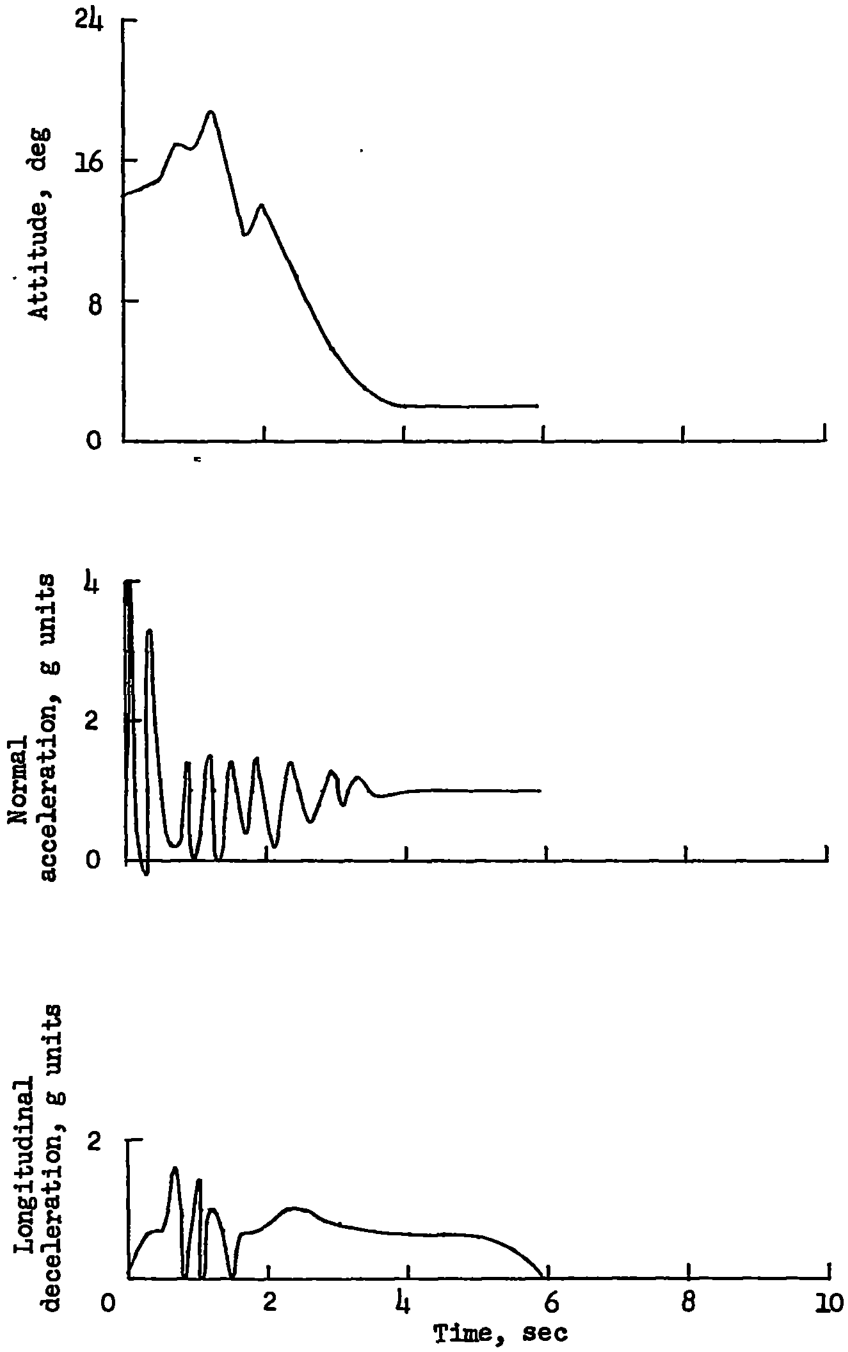


(c) 206-gallon tank. Fineness ratio, 4.76.



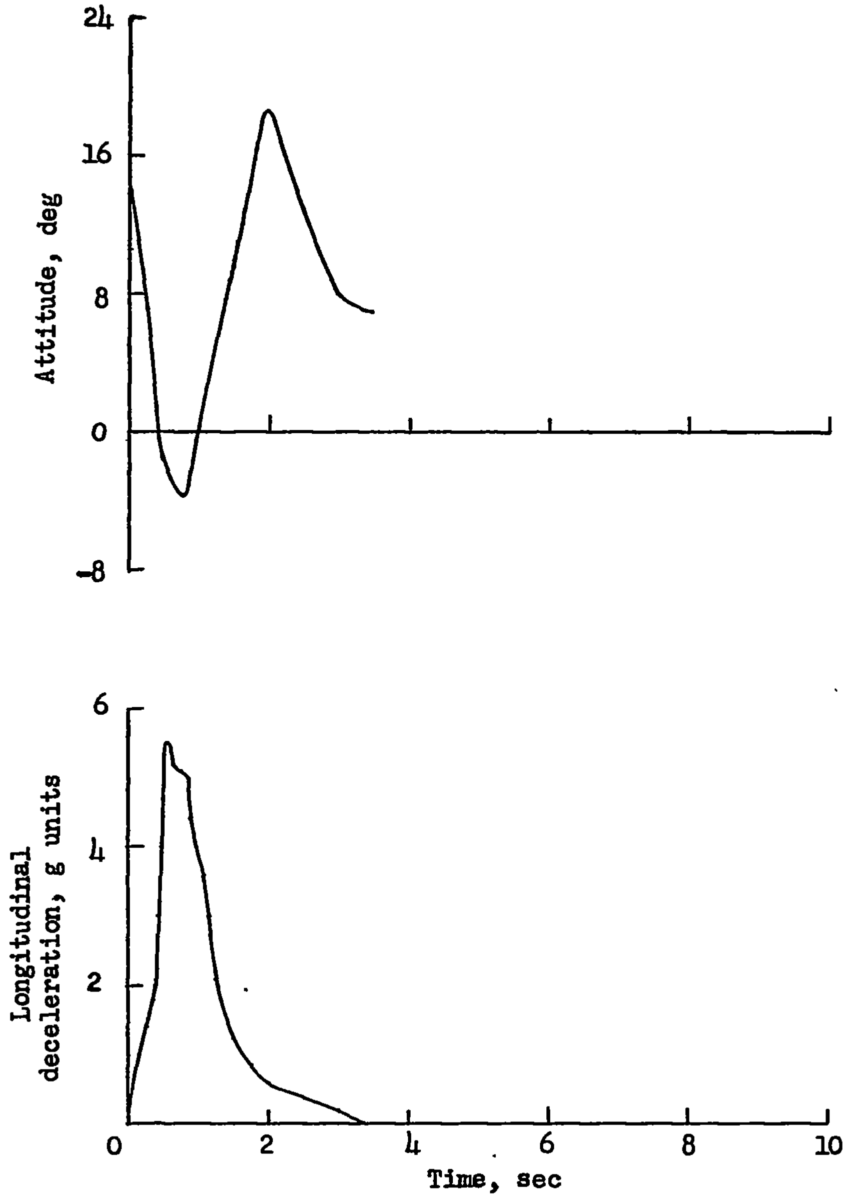
(d) Cross-section modifications.

Figure 3.- Tank configurations tested. All linear dimensions are in inches. Values are full-scale.



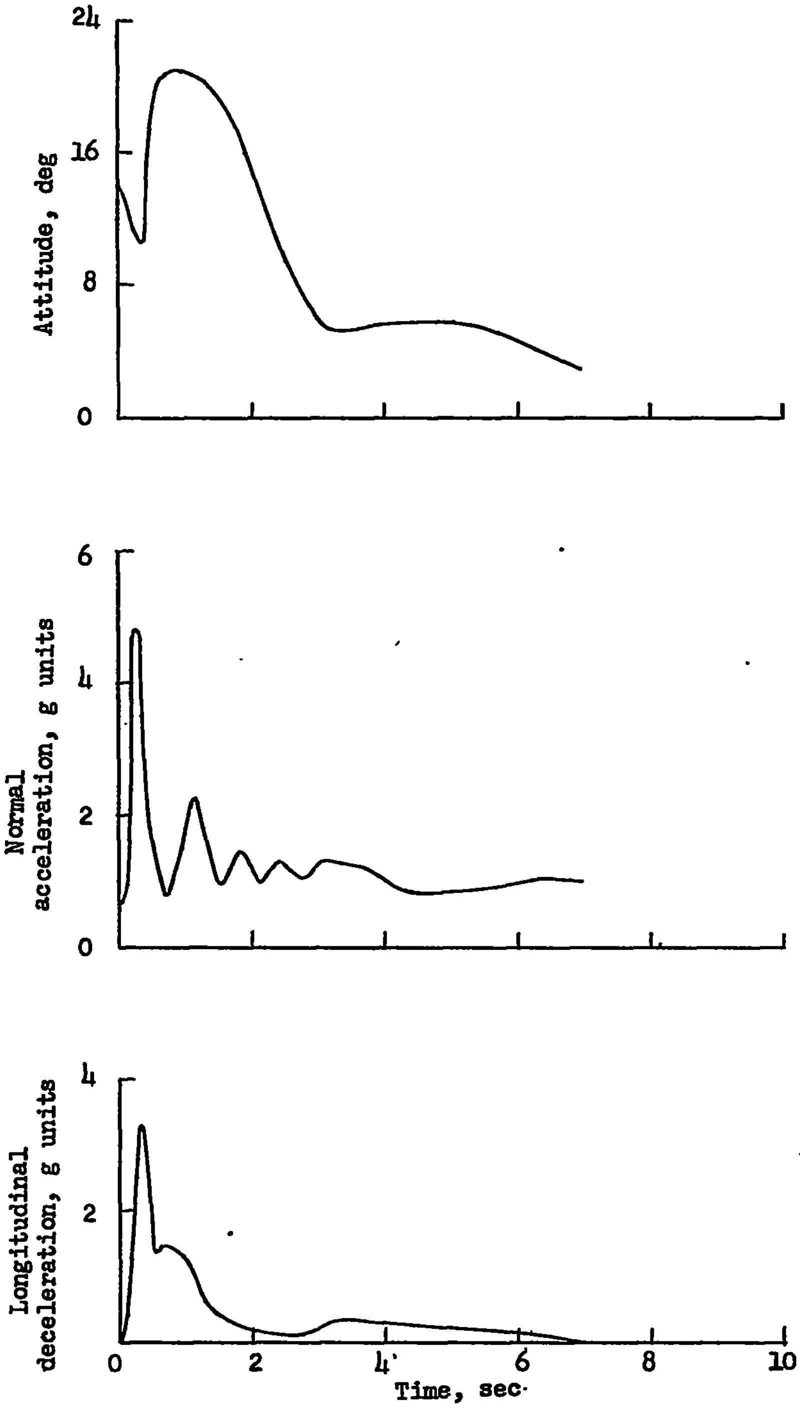
(a) Basic model.

Figure 4.- Typical time histories of attitude, normal acceleration, and longitudinal deceleration. All values are full-scale.



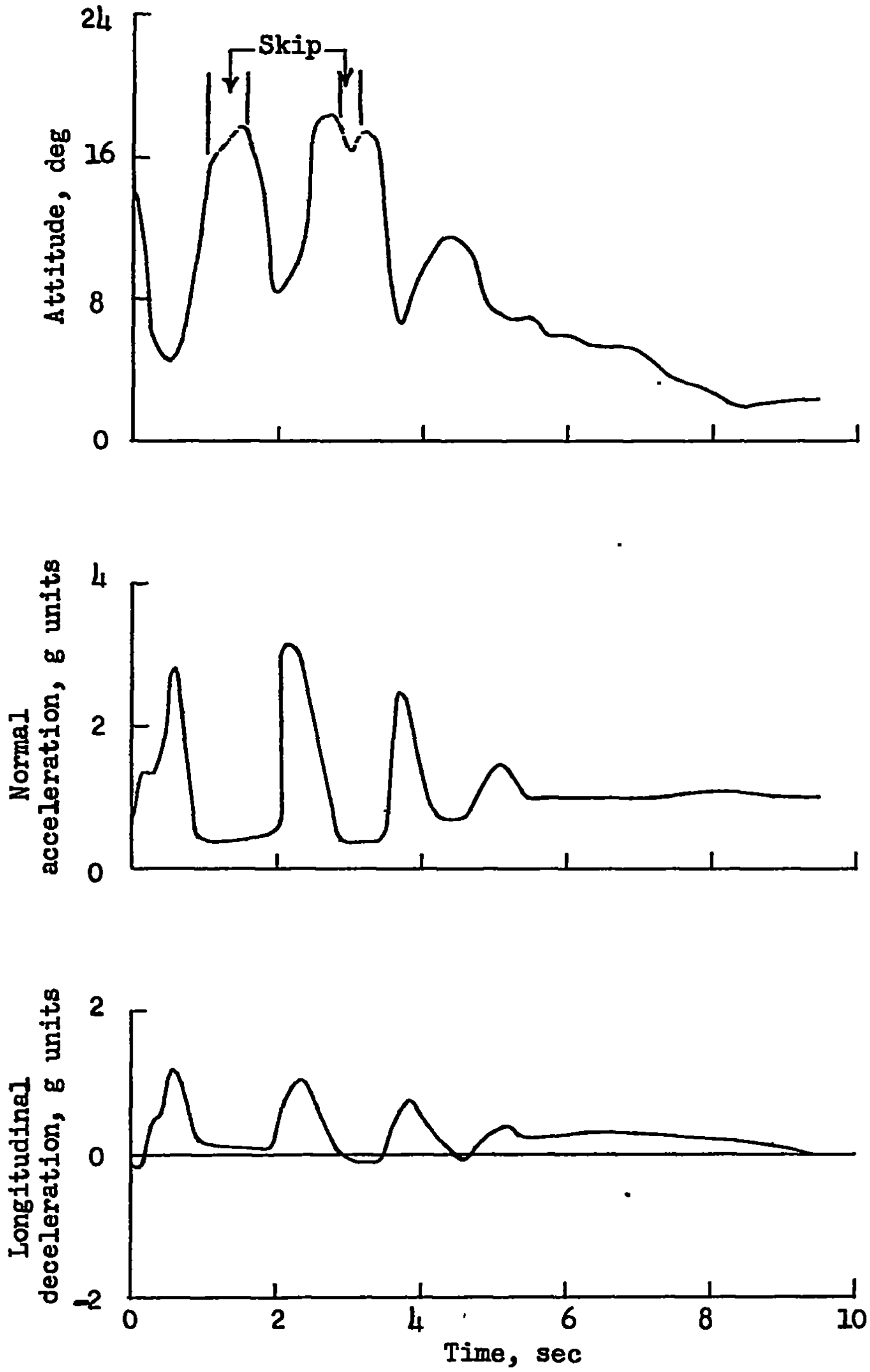
(b) Model with original 206-gallon tanks.

Figure 4.- Continued.



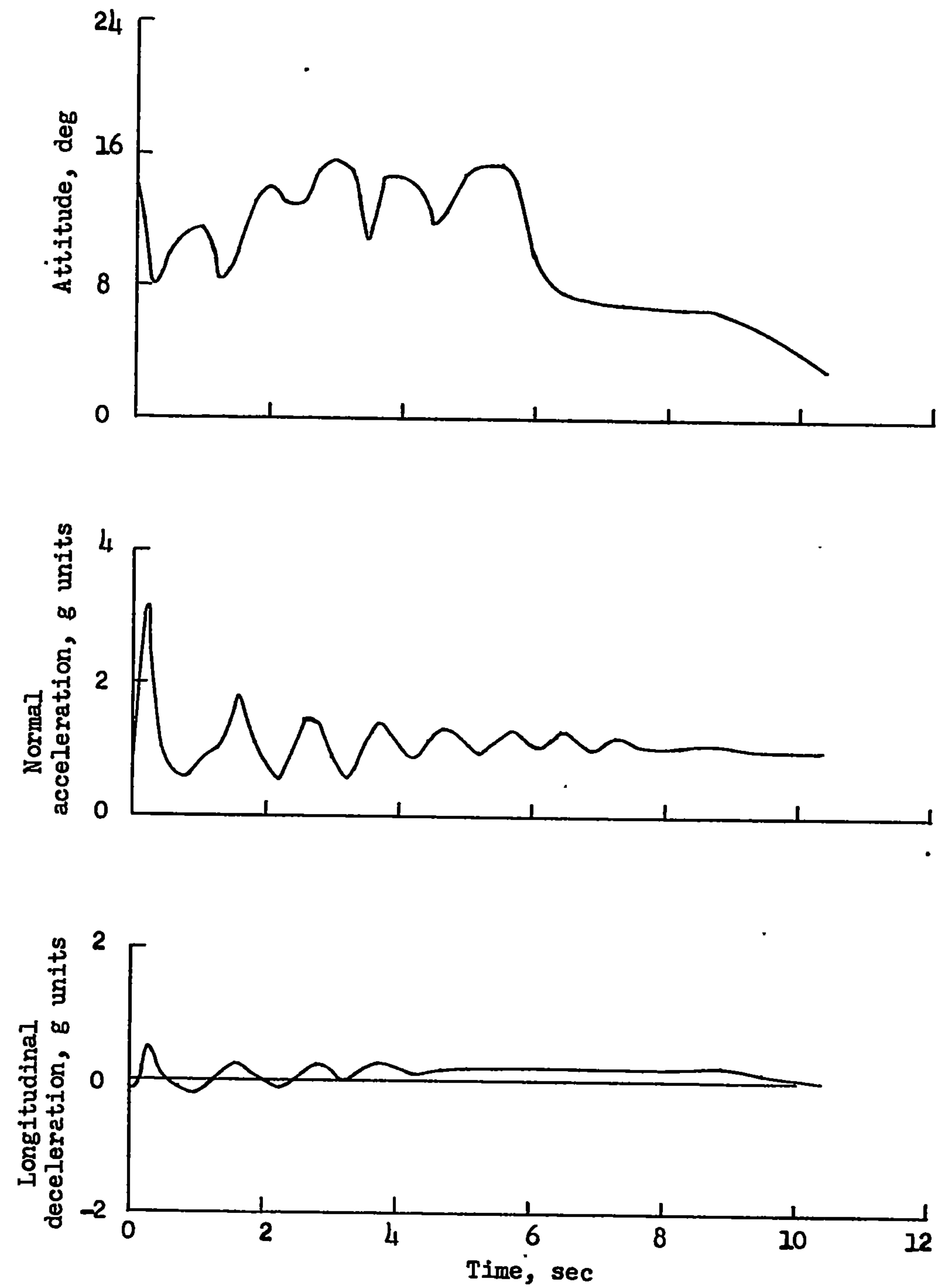
(c) Model with 450-gallon circular-cross-section tanks.

Figure 4.- Continued.



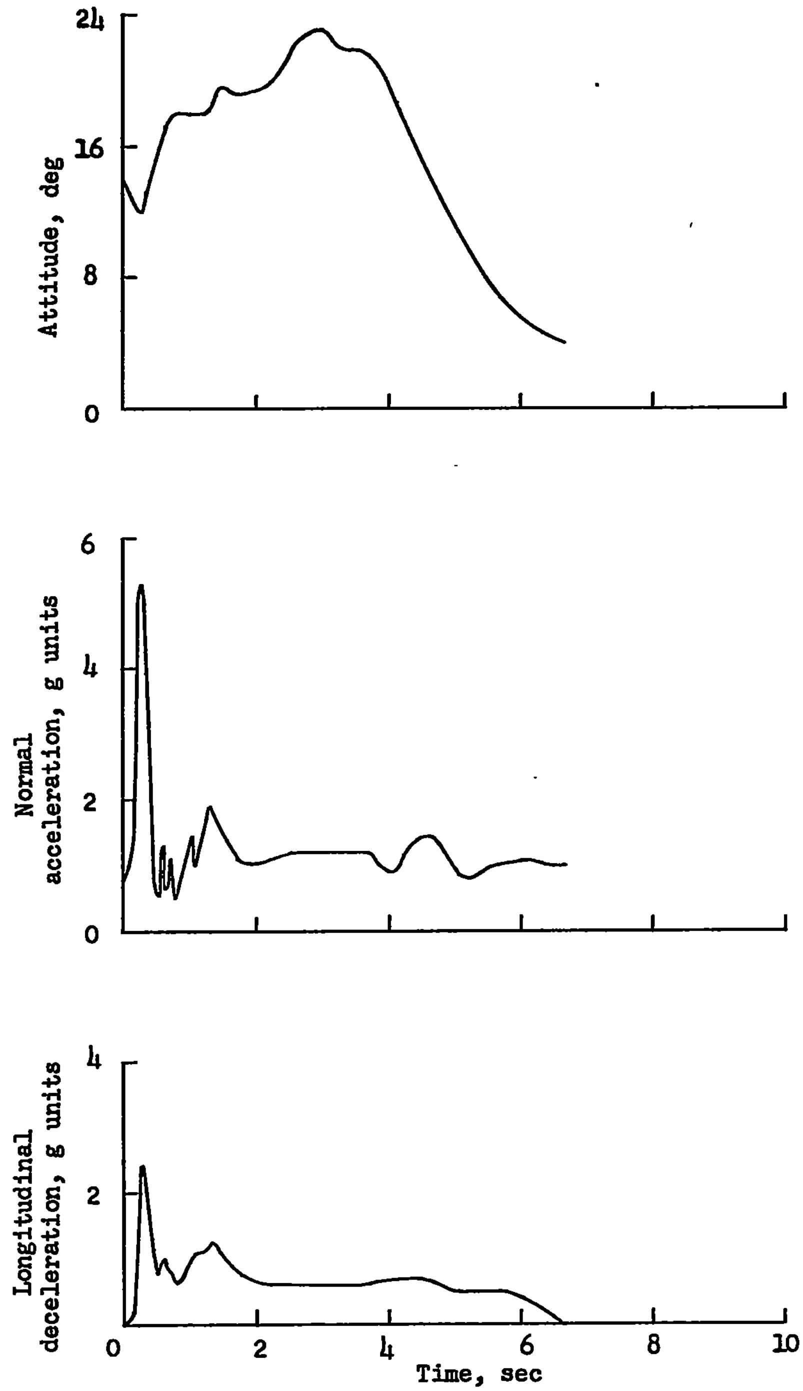
(d) Model with 450-gallon circular-cross-section tanks with chine strips.

Figure 4.- Continued.



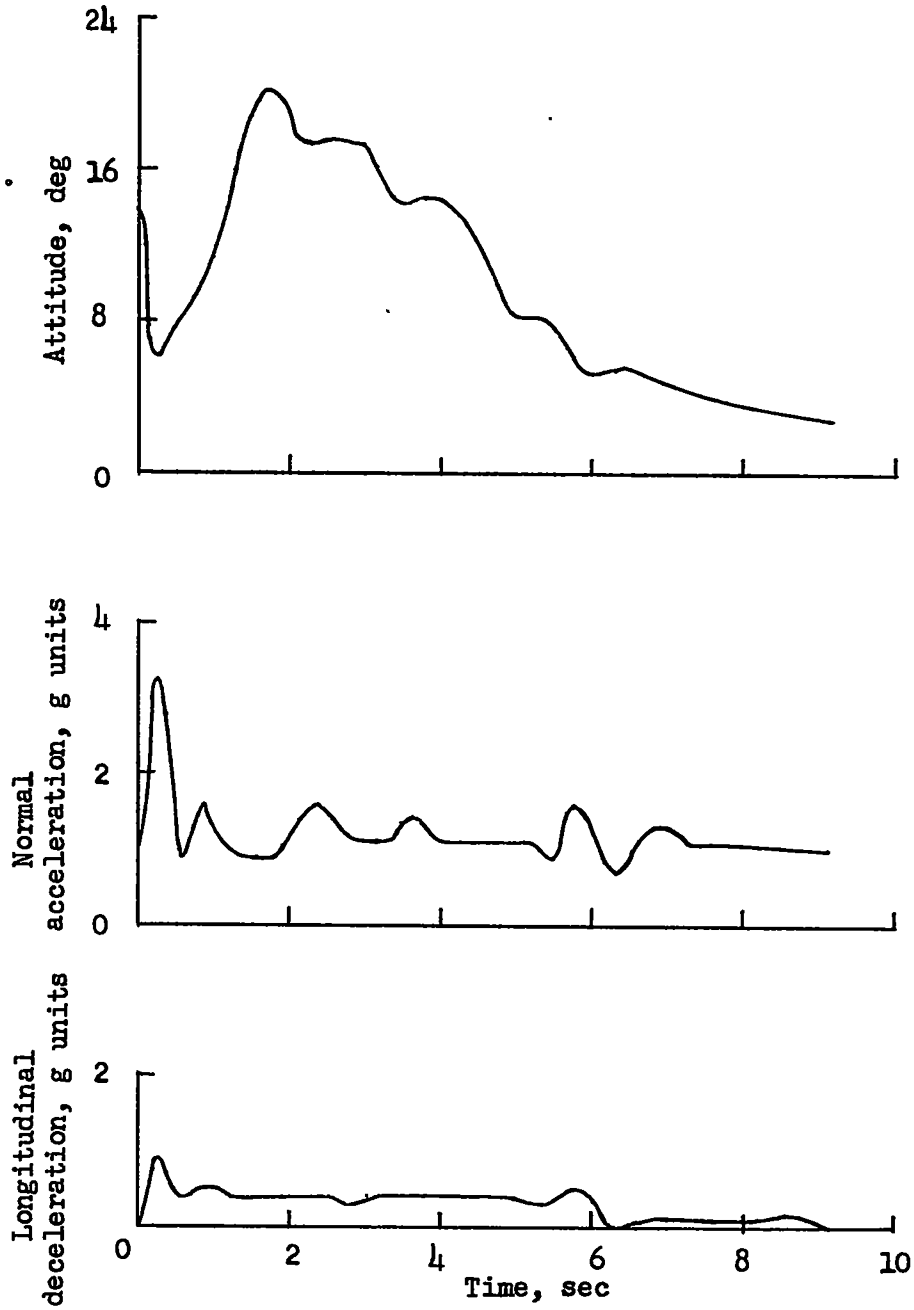
(e) Model with 450-gallon tanks with 20° dead-rise bottom.

Figure 4.- Continued.



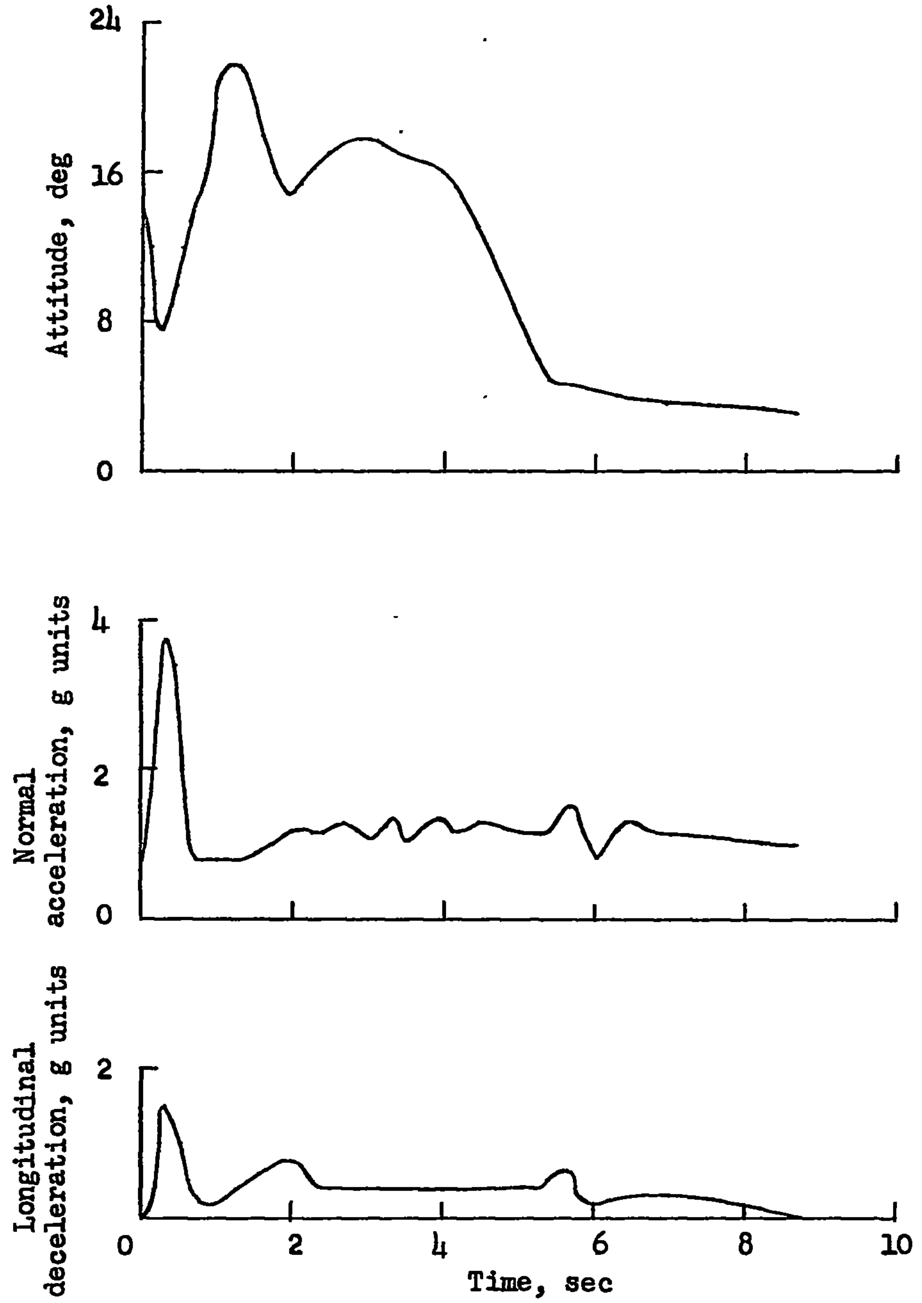
(f) Model with 260-gallon circular-cross-section tanks.

Figure 4.- Continued.



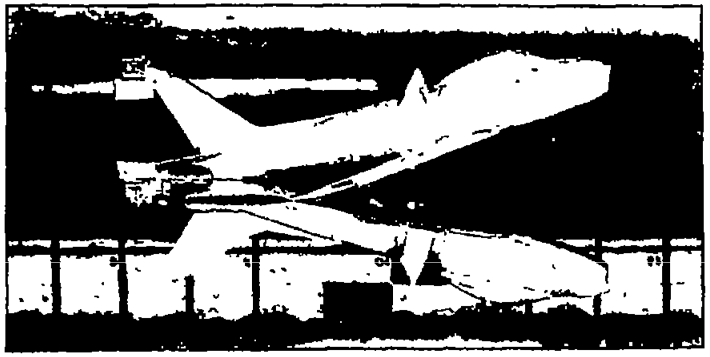
(g) Model with 260-gallon circular-cross-section tanks with chine strips.

Figure 4.- Continued.



(h) Model with 260-gallon tanks with 20° dead-rise bottom.

Figure 4.- Concluded.



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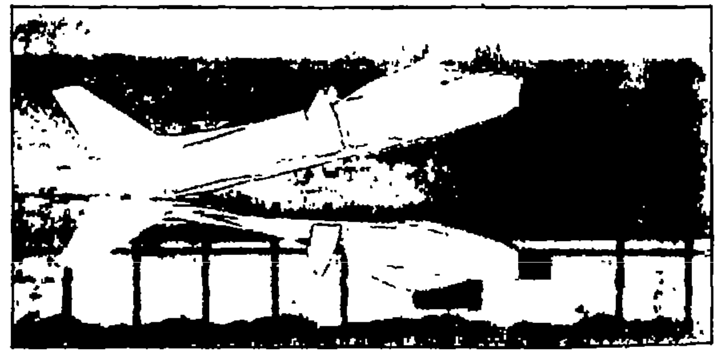
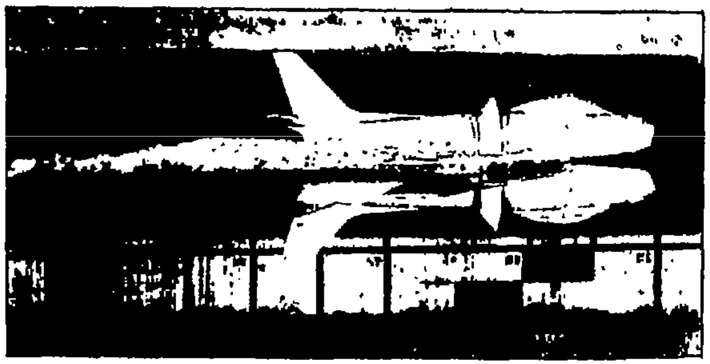


170 feet

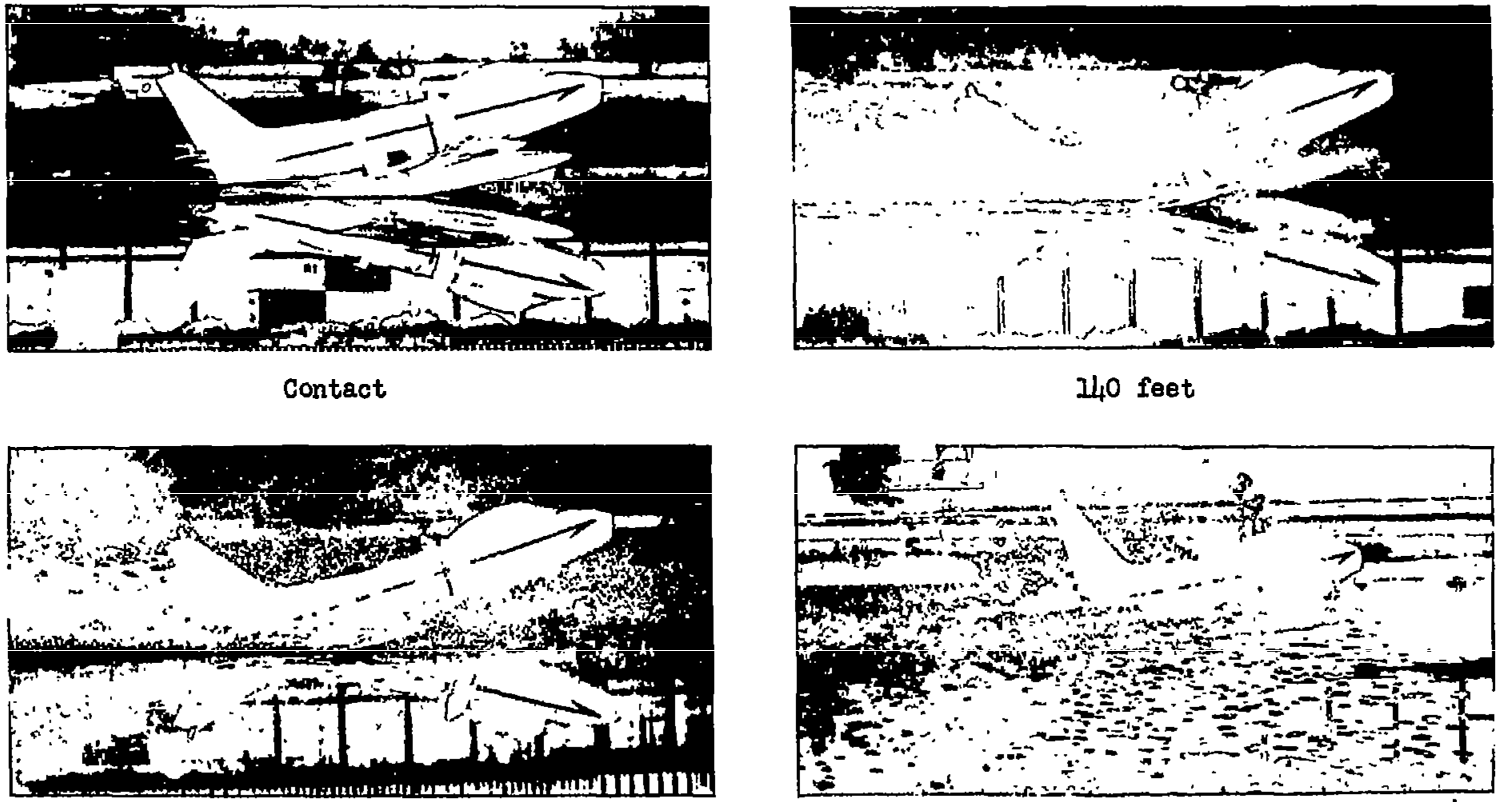


400 feet

520 feet

(a) Basic model. L-92475

Figure 5.- Sequence photographs of model ditchings. Distances are full-scale.



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140 feet

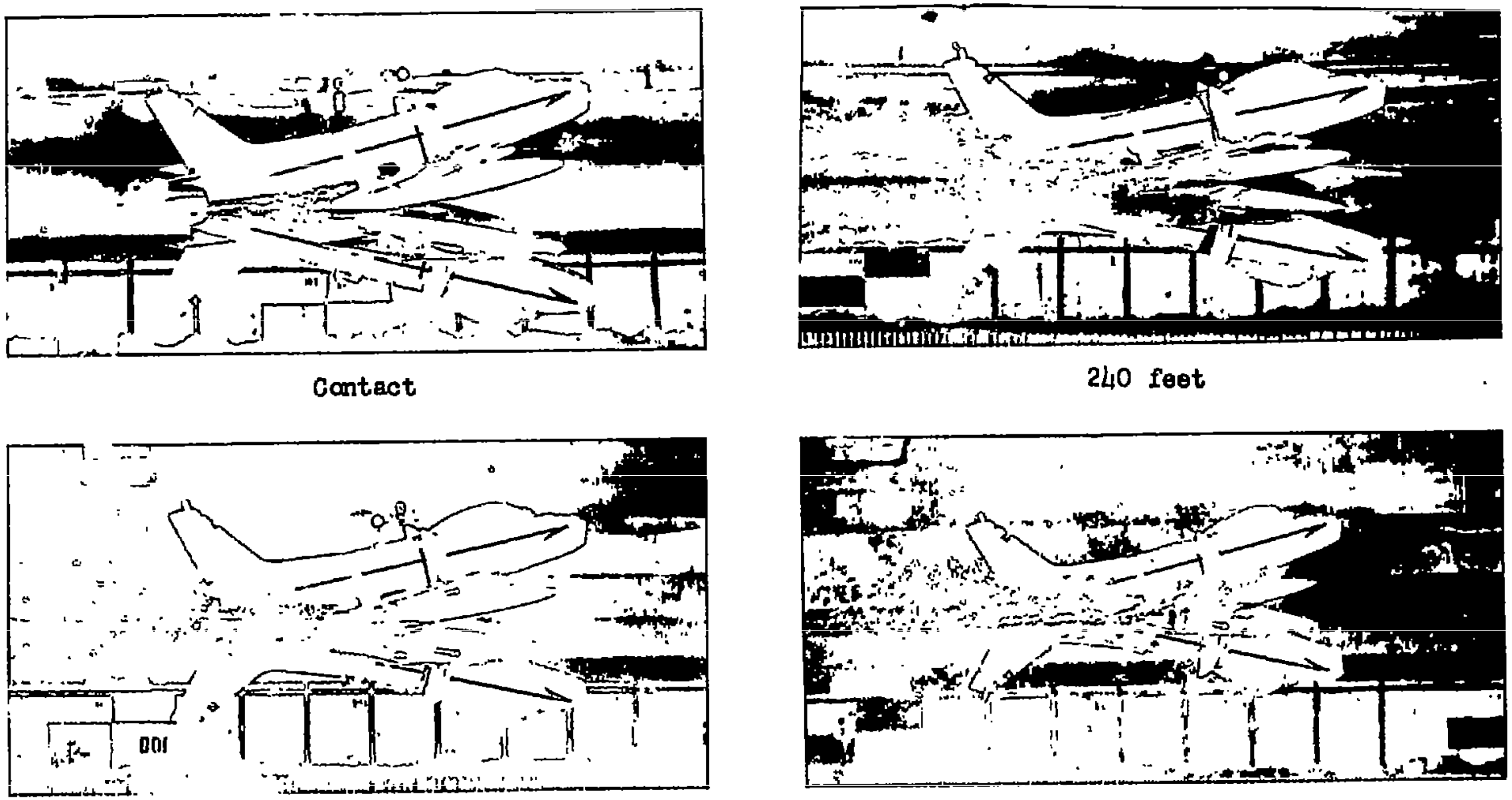
230 feet

340 feet

L-92476

(b) Model with 450-gallon circular-cross-section tanks.

Figure 5.- Continued.



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240 feet

540 feet

940 feet

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(c) Model with 450-gallon tanks with 20° dead-rise bottom.

Figure 5.- Concluded.

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